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ECE 637
Lab 4: Pointwise Operations and Gamma

1. Histogram of an Image

1. Two images, *race.tif* and *kids.tif*, and their labeled histograms

Figure 1: race.tif

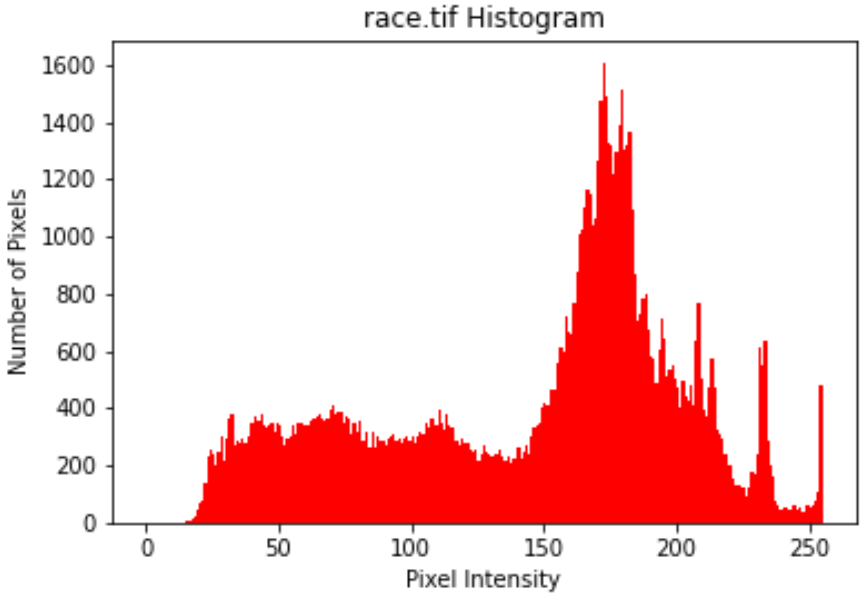

Figure 2: Histogram of race.tif

Figure 3: kids.tif

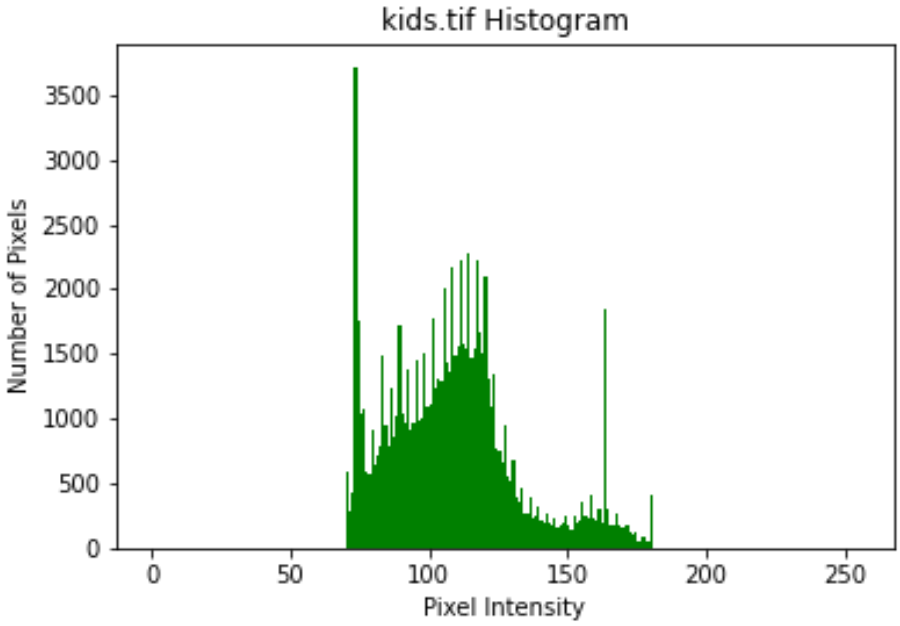

Figure 4: Histogram of kids.tif

2. Histogram Equalization

1. Function *equalize()*:

```
def equalize(X):
    L = 256
    m, n = np.shape(X)
    shape = (m, n)
    Z = np.zeros(shape)
    Fx_hat = np.zeros((1,256))

    h = np.histogram(X,bins=np.linspace(0,255,256))

    Fx_hat = np.cumsum(h[0])/np.sum(h[0])

    Ymax = np.max(Fx_hat)
    Ymin = np.min(Fx_hat)

    for i in range(m):
        for j in range(n):
            Z[i,j] = (L - 1)*((Fx_hat[X[i,j]+1] - Ymin)/(Ymax - Ymin))

    return Z, Fx_hat
```

Figure 5: equalize() Function

2. Labeled plot of $\hat{F}_x(i)$ for the image *kids.tif*

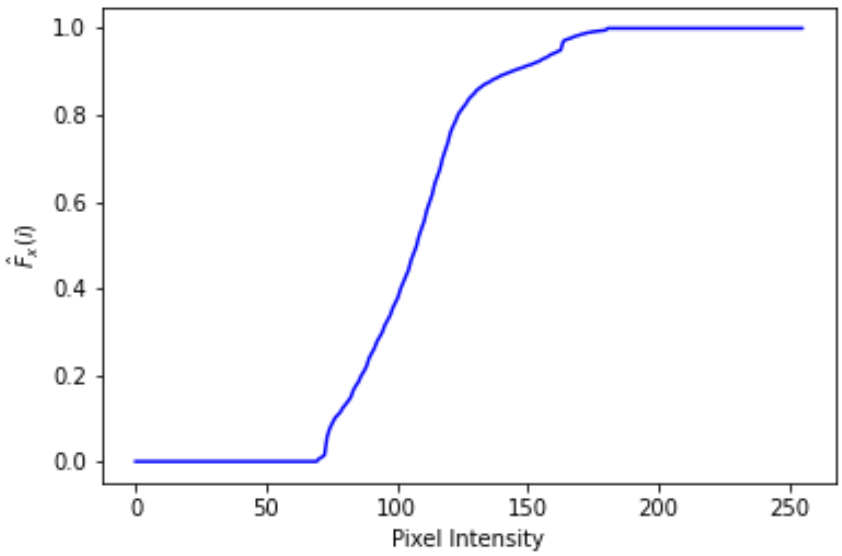

Figure 6: $\hat{F}_x(i)$ Plot for kids.tif

3. Labeled plot of the equalized image's histogram

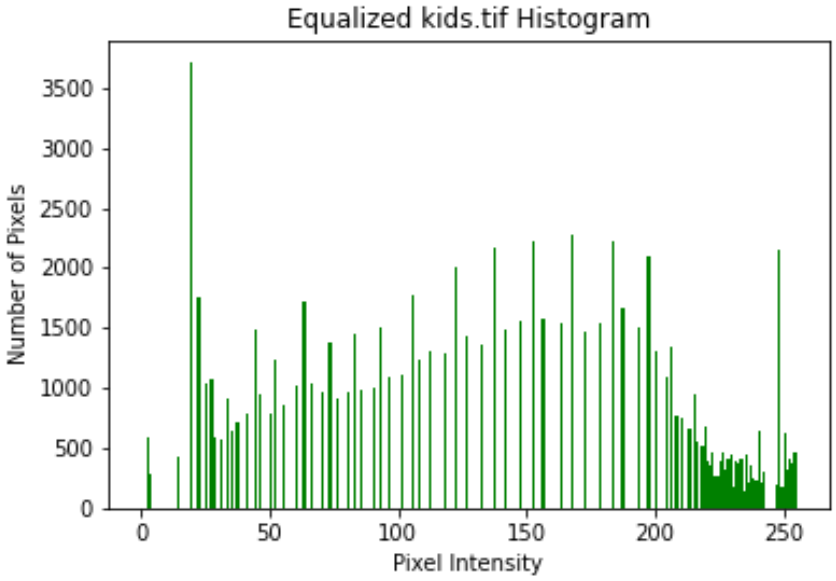

Figure 7: Equalized kids.tif Histogram

4. Equalized image

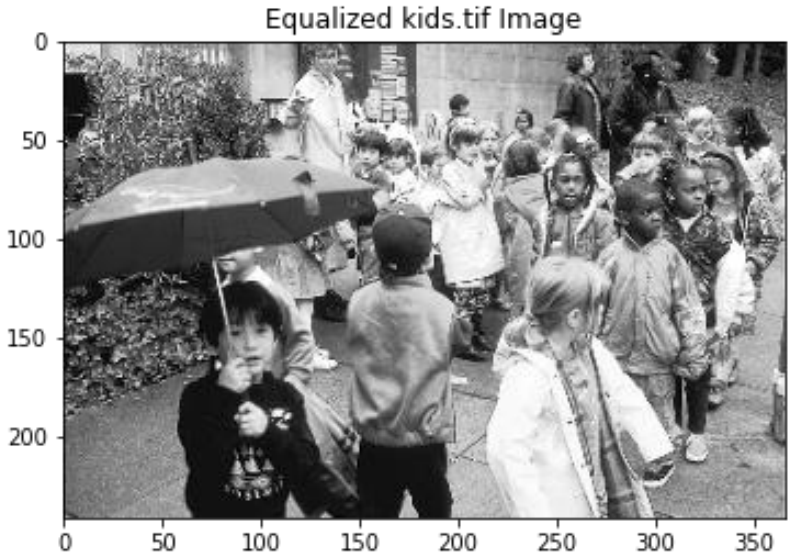

Figure 8: Equalized kids.tif Image

3. Contrast Stretching

1. Function *stretch()*:

```
def stretch(X, T1, T2):
    m, n = np.shape(X)
    shape = (m,n)
    output = np.zeros(shape)

    for i in range(m):
        for j in range(n):
            if X[i,j] > T1:
                if X[i,j] < T2:
                    # output/X = rise/run --> output = rise/run * X
                    output[i,j] = (255/(T2-T1))*(X[i,j] - T1)
                else:
                    output[i,j] = 255

    return output
```

Figure 9: stretch() Function

2. Transformed image and its histogram

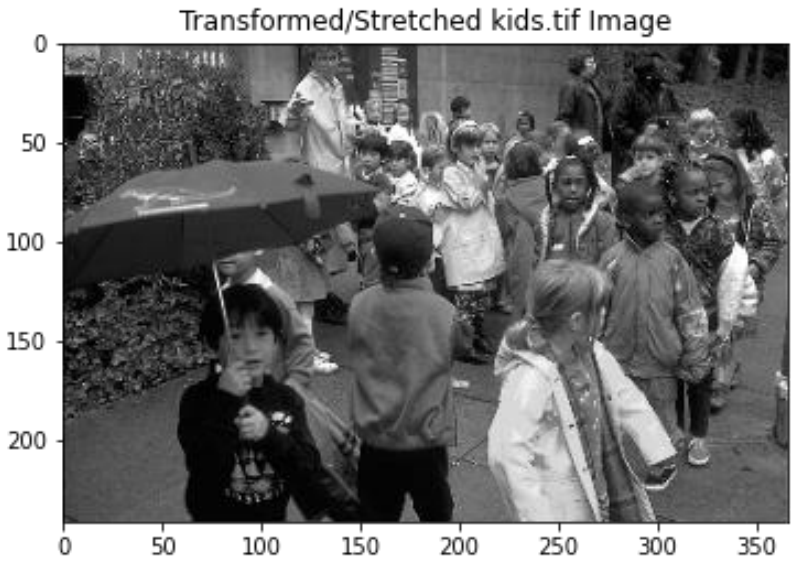

Figure 10: Transformed kids.tif Image

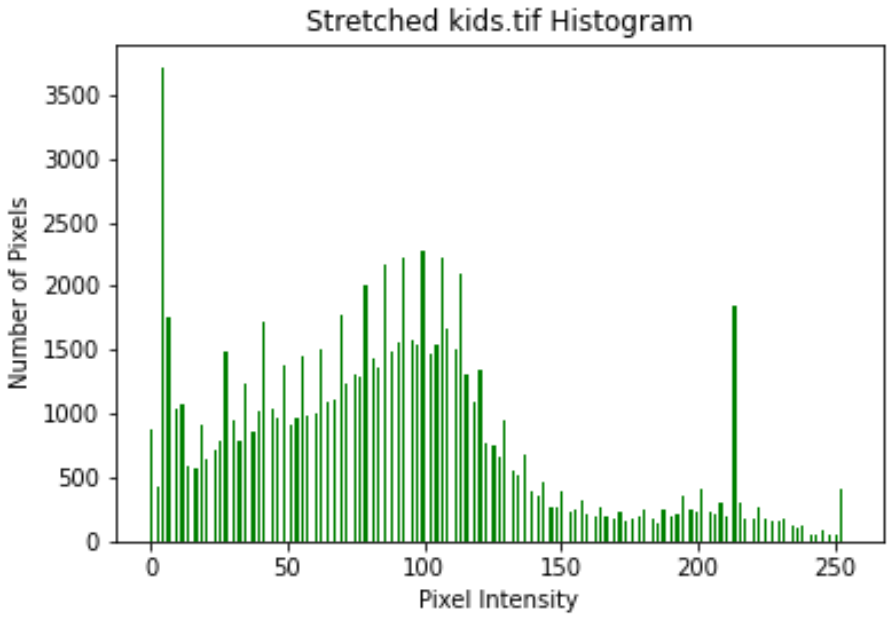

Figure 11: Transformed kids.tif Histogram

4. Gamma (γ)

1. Setting the Black Level and Picture of Your Monitor

* No Deliverables *

2. Determining the Gamma of Your Computer Monitor
    a. Image corresponding to the matching gray level

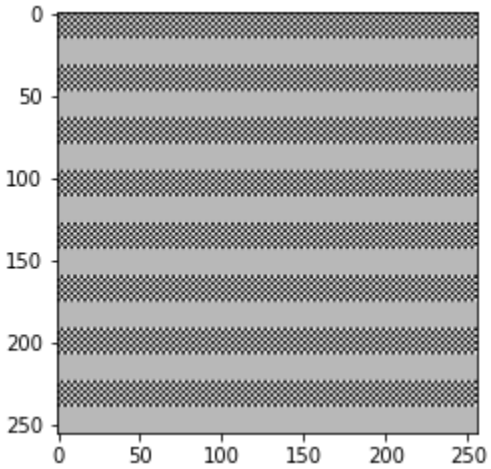

Figure 12: Image Corresponding to Matching Gray Level, g = 184

    b. Derivation of the expression which relates the matching gray level to the value of gamma

$$I_c = \frac{(I_{255} + 0)}{2};\ I_g = I_{255}\left(\frac{g}{255}\right)^{\gamma}$$

$$Find\ \gamma: I_g = I_c$$

$$I_{255}\left(\frac{g}{255}\right)^{\gamma} = \frac{(I_{255} + 0)}{2}$$

$$I_{255}\left(\frac{g}{255}\right)^{\gamma} = \frac{I_{255}}{2}$$

$$\left(\frac{g}{255}\right)^{\gamma} = \frac{1}{2}$$

$$\log\left(\left(\frac{g}{255}\right)^{\gamma}\right) = \log\left(\frac{1}{2}\right)$$

$$\gamma \log\left(\frac{g}{255}\right) = \log\left(\frac{1}{2}\right)$$

$$\gamma = \frac{\log\left(\frac{1}{2}\right)}{\log\left(\frac{g}{255}\right)} = \frac{\log(1) - \log(2)}{\log(g) - \log(255)} = \frac{-\log(2)}{\log(g) - \log(255)}$$

c. Values of the measured gray level and the measured gamma

$$g = 184$$

$$\gamma = \frac{-\log(2)}{\log(g) - \log(255)} = \frac{-\log(2)}{\log(184) - \log(255)} = 2.124$$

Measured Gray Level	Measured Gamma (γ) Value
184	2.124

3. Gamma Correction
   a. Original and corrected images, with value of gamma used indicated in title

Figure 13: Original linear.tif Image

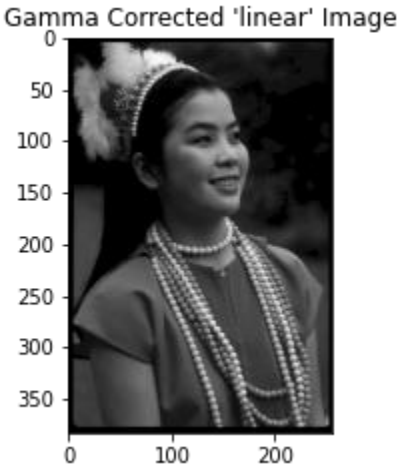

Figure 14: Gamma Corrected linear.tif Image, $\gamma = 2.12$

   b. Formula used to transform the original image

$$x = 255\left(\frac{y}{255}\right)^{\frac{1}{\gamma}}$$

c. Corrected image, properly labeled

Figure 15: Original gamma15.tif Image

Figure 16: Corrected gamma15.tif Image

d. Procedure used to change the gamma correction of the original image
   i. Transform pixel data back to un-corrected gamma state: Calculate y_1 from x_1, where x_1 is the input data of image *gamma15.tif* and γ_1 is the current gamma correction of the image

$$y_1 = 255\left(\frac{x_1}{255}\right)^{\gamma_1}$$

   i. Re-correct for desired gamma value: calculate x_2 from y_1, where γ_2 is the gamma correction value for the monitor being used

$$x_2 = 255\left(\frac{y_1}{255}\right)^{\frac{1}{\gamma_2}} = 255\left(\frac{255\left(\frac{x_1}{255}\right)^{\gamma_1}}{255}\right)^{\frac{1}{\gamma_2}} = 255\left(\frac{x_1}{255}\right)^{\frac{\gamma_1}{\gamma_2}}$$

Solution: Apply a gamma correction of $\gamma = \frac{\gamma_1}{\gamma_2} = \frac{1.5}{2.12}$ to the original data from *gamma15.tif*